

Worlds and Systems in Early Modern Europe

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Abstract. The structure, formation and evolution of the Universe were some of the main topics in the scientific debates during the 17th and 18th centuries in Europe. They involved novel ideas on the cosmos, which concerned aspects that were not considered before so emphatically, and which were fundamental for the future development of astronomy. This paper presents a brief account of several milestones within the gradual definition of pre-galactic systems: the historical role of the tradition of the plurality of worlds, the significance of Descartes, and the introduction of the Milky Way and nebulae in the discourses around the cosmic structure.

1. Introduction

Before the gradual definition of galaxies that took place one century ago, the formation, evolution, and structure of the Universe were put into question in Europe, with a special intensity during the early modern period.¹ Many authors, even without enough observational data of the most basic physical properties of distant objects, attempted to give explanations to the nature and constitution of the cosmos far beyond the Solar System.

One cannot expect to find in the 17th and 18th centuries precise definitions of the characteristics of galaxies in terms that we now understand. The lack of scientific information at that time makes this an impossible task. Therefore, when reading astronomical texts from this period we must be aware of the huge gap that separates us from them with regard to the state of astronomy and, consequently, we cannot demand that they provide in this context useful, measurable, or testable ideas for current astronomers.

Notwithstanding, the debates and hypotheses from this period fueled the further development of science. Even the discourses that remained within a religious or philosophical context triggered a field for discussion, pointing out topics and research areas that were the grounds for future theories and observations. Some authors may be considered from our perspective obscure thinkers or defenders of erroneous pseudo-scientific statements; however, they were also significant, insofar as they dealt with non-established – and, sometimes, non-accepted – ideas nevertheless containing key elements for setting the right (big) questions astronomy had to answer.

Subjects from the 17th and the 18th centuries such as the plurality of worlds, the vortex hypothesis, or the (in most of the cases highly intuitive) ideas around the nature of the Milky Way and the nebulae, are usually disregarded for not having significant

¹More precisely from the late 16th to the 18th centuries.

scientific value. However, without these debates, the formulation of ‘right’ theories could not have taken place.²

In this text I present some basic considerations for a better understanding of certain aspects from the history of astronomy in the early modern period that made possible a gradual awareness of the actual structure of the Universe: the vortex hypothesis, the plurality of worlds, and the first speculations on the Milky Way and the nebulae, which were discussed in Europe by many scientists and philosophers, such as Descartes, Swedenborg, or Kant, during the 17th and 18th centuries. Just after this period William Herschel focussed the investigations on nebulae, finally leading to modern galaxy studies.

2. The historical significance of the plurality of worlds

One of the most radical starting points for the ‘new astronomy’ that arose at the end of the 16th century and consolidated in the course of the 17th and 18th centuries in Europe was the idea that the cosmos is composed of a plurality of worlds. This notion involved many innovative ideas, which were widely discussed together or separately but, in any case, which were perceived by the authors of that time as a single and solid tradition. It generated a trend in scientific and philosophical texts that contributed, on the one hand, to put emphasis on the question about the structure of the Universe and, on the other, to popularize scientific topics in an unprecedented way.

The Russian-French historian of science Alexandre Koyré (1892–1964) proposed in the middle of the 20th century a very lucid approach to early modern science based on the ideas around the structure of the Universe as a whole (Koyré 1957). His inquiry was basically centered on how authors from the 17th and 18th centuries tackled the question of the infinitude of the Universe. This way of approaching history, in which Giordano Bruno (1548–1600) is more relevant and revolutionary than Copernicus (1473–1543), puts forward important (and until then mostly forgotten) elements to comprehend the change of mentalities that gradually led to the modern world. While Koyré attracted our attention to the radical transformation that took place during this time with regard to the general notions on the structure of the Universe (his famous statement “from a closed world to an infinite Universe”), a critical approach to the tradition of the plurality of worlds can provide the most relevant clues for understanding how the particular constitution of this new (infinite or, at least, unprecedentedly enormous) Universe was defined.

In the early 1980s the tradition of the plurality of worlds was subjected to two major examinations that are still a reference for the field: the well-known investigations by Steven J. Dick (1982) and Michael J. Crowe (1986). In spite of the significance of these texts in pointing out the necessity of integrating this topic within a serious

²For instance, even Slipher’s initial redshift measurements at Lowell Observatory in Flagstaff were motivated by some of these ‘unfortunate’ discussions. Let us remember that Percival Lowell (1855–1916) paid great attention to the nebular hypothesis of planetary system formation and was a fervent defender of the most controversial aspects of the plurality of worlds, i.e. the existence of extraterrestrial life. See the text by Robert W. Smith in this volume for an insight into this aspect of Slipher’s work.

Slipher is a good example of the change of times, being placed between the long tradition of speculative and non-testable hypotheses represented by Lowell, and the definitive modernization of astronomy that was partially consolidated after his measurements. For understanding the context of Lowell’s ideas in this respect see Crowe (1986).

history of astronomy, they both put the emphasis on one of the aspects regarding the plurality of worlds, namely the possible existence of extraterrestrial life. However, even though it was a very important topic in the history of astronomy, the most ground-breaking element of this tradition concerned the specific notions around the structure of the Universe, from which the possible existence of life in other heavenly bodies was a side-effect, and not the core of the hypotheses.

The scientific, philosophical, and even literary tradition of the plurality of worlds generated a general debate about the possible constitution of the cosmos beyond the Solar System³ that stimulated much research, conjecture, and passionate discussion on the topic throughout Europe.

From our perspective, at first glance one may be tempted to undervalue these contributions for not being based on reliable scientific data. However, these ideas can seem astonishing if we put it this way: in spite of the lack of information, only starting from very simple observations and mainly proceeding by reasoning, these authors managed to foresee that the Universe goes far beyond the Solar System and the observable stars, that there are many autonomous and interconnected systems similar to ours (as hypothesized in the first stages of the plurality of worlds⁴), and that the Milky Way and the nebulae are evidence for understanding the general structure (such as Wright of Durham or Kant considered, at a time when the intense investigation of nebulae had not yet started⁵). Most of these authors were not able to give precise (or accurate) explanations of the physical properties of the other systems, nor to determine their size or their distances with respect to us. But, in view of the state of the astronomical knowledge within this context at that period, this is not a surprise. These early notions, though imprecise or inaccurate compared to our current understanding, were nevertheless crucial in establishing the framework of the field that had to be explored in the future.

The discussions on the plurality of worlds were not specific references dispersed in various books. Instead, this set of ideas constituted a historical tendency, a body of knowledge that put specific topics into question and generated a particular tradition of authors and texts. As a matter of fact, without taking this chapter of our history into serious consideration, it is impossible to fully understand the early roots of modern notions on the structure of the Universe.

³The term *world* was commonly used to refer to a complete unit within the puzzle of the Universe, i.e. a system containing (at least potentially) all the elements present in the Solar System: a central star and several planets orbiting around it. These planets could have related satellites and could be inhabited. As mentioned above, the main references in the secondary literature about the plurality of worlds highlight this last element, rather than giving a comprehensive approach to all the implications that the worlds involve.

⁴See Fontenelle (1686), one of the more important texts that popularized this field.

⁵When Kant published his *Theory of Heaven*, William Herschel, the astronomer who would systematically look for and observe nebulae, was only 17 years old. Nevertheless, it is important to remember that Herschel was not the first person who noticed the existence of nebulae. Ancient astronomers had observed many of them without the aid of a telescope. References to nebulae appear also in other cultures. For instance, the very first image of the Andromeda Nebula was published by the Arab astronomer al-Sufi in *Kitab al-suwar al-kawakib al-thabitha* [The Book of Fixed Stars] around 964. For a brief introduction to the main pre-Messier studies on nebulae see Jones (1969, pp. 21-8).

3. The leading role of Descartes' cosmology

A similar role to Giordano Bruno in Koyré's analysis is played by René Descartes (1596–1650) within the history of the plurality of worlds,⁶ even though he did not focus on the 'worlds' themselves, but rather on the vortices.⁷ With his physical model, Descartes revolutionized the way of thinking about the structure of the Universe. Furthermore, unlike Bruno, he was not prosecuted for his thinking, such that this kind of debate became generally accepted.

In his major scientific texts Descartes (1644, 1664) developed the first serious attempt in early modern Europe to understand the nature and physics of extrasolar systems. He postulated the probable existence of many entities outside the Solar System, which should be similar to it in their basic characteristics but, at the same time, independent, autonomous, and able to interact among each other.

Descartes not only described a Universe made up of independent and distant systems, but also how these vortices were formed and were subjected to an ongoing evolution. Thus, the works mentioned above were entirely devoted to explaining the formation, evolution and construction of the Universe. During the centuries that preceded him, the origin of the Universe was sometimes discussed, but mostly within the religious framework of the Bible (more precisely the Book of Genesis). Through his works, Descartes initiated the trend of taking cosmology into consideration strictly within a scientific perspective. Afterward, other authors tackled the origin and evolution of the Universe as a normal topic in astronomy, while there were still authors who confused them with religious notions. This was not the case with Descartes; he kept religious explanations out of his understanding of the physical world.

Fascinated by the idea of a vast Universe composed of a multitude of systems, many authors embraced the vortices as the most revolutionary hypothesis in astronomy

⁶In the sense of being the main figure within the history of a specific concept that modernized the picture of the Universe – infinity in the case of Bruno, and the existence of many extrasolar systems in Descartes'. Although both ideas were discussed since ancient times, Bruno and Descartes initiated a new tradition making these concepts central in their respective worldview.

One may think that Giordano Bruno would be the principal authority within the plurality of worlds. However, he was not. Let us remember that the Inquisition condemned him to death and burned him in Rome in 1600 for his heretical thoughts. His misfortune made him a forbidden reference and, consequently, many later authors of the plurality of worlds never cited Bruno. Instead, they followed Descartes' physics – be it for defending it, or for contradicting it.

⁷We cannot forget that the vortices hypothesis had a parallel and autonomous development with respect to the plurality of worlds. Descartes defined the structure and evolution of the Universe in terms of vortices. According to him, there were many – literally, an "indeterminate" number of – systems similar to the Solar System, which were made of a fluid matter in continuous motion. Owing to the fluidity and the intrinsic motion (hence the name of vortices), the systems (and therefore the entire Universe) were in constant change. They were autonomous entities but, at the same time, interacted with the adjacent vortices, colliding with them, causing the extinction of weaker or smaller systems, or increasing their size by merging with them. Descartes explained the properties of the celestial matter as a basis to understand the nature of cosmic evolution. However, he did not consider the 'worlds' as his followers did. For instance, the debate on extraterrestrial life was irrelevant for him. For a comparison between the Cartesian vortices and the picture of the Universe according to modern cosmology see Ayala & Forero-Romero (2011), also available online at <http://arxiv.org/abs/1110.6772>.

so far, which became the paradigm for a secularized science.⁸ This new corpus of ideas achieved exceptional popularity mainly owing to the great success of the book *Conversations on the Plurality of Worlds*, published by Bernard Le Bovier de Fontenelle (1657–1757) in Paris in 1686 and republished again and again in many countries and languages throughout the course of several centuries (see Fontenelle 1686; Ayala 2011). Fontenelle, following Descartes' ideas, helped in a significant way to change the general opinion of Europeans regarding the structure of the Universe.

At that point in history, neither the Milky Way nor the nebulae had a prominent position in the explanations on the structure of the Universe. Instead, the Solar System – or the solar vortex, which according to the Cartesian terminology, contained the Solar System – was the paradigmatic piece in the constitution of the cosmos. In other words, in the pre-galactic cosmos, the Solar System was the referential unit. Although the Cartesian vortices and the worlds were not defined according to the dimensions or properties of the galaxies, they represented a necessary initial step within a gradual change of paradigms regarding the constitution of the Universe.⁹

4. Swedenborg's cosmos: "Expansion" in an "active space"

One century after the publication of Descartes' texts, his vortex hypothesis was still considered a valid model. This was in spite of the supporters of Newton, who usually set them in opposition and, as a result, systematically discarded all ideas coming from the French scientist. One of the late advocates of the vortices was the Swedish scientist and theologian Emanuel Swedenborg (1688–1772), a 'mystic scientist' in a similar way to Thomas Wright of Durham (in fact they were contemporaries; see Sect. 5), as he was also driven by scientific and religious motivations without making any distinction between them. Nevertheless, the most analytical and scientific part of their hypothesis was relevant in view of the later development of science, especially in the context of cosmology.

In *The First Principles of Natural Things* (Swedenborg 1743),¹⁰ Swedenborg developed a complete description of the formation and evolution of the Universe according to the vortices, while providing many of the details that had remained unelaborated by Descartes. He described the Universe in terms of its transformation processes: the many systems are (after Descartes) in a constant process of collision, merging, vanishing, and change. The systems of his cosmos were being created or destroyed at all times. He conceived the cosmic structure as a Russian doll, in which all elements were contained within larger structures:

⁸Because his explanations were independent from religious thought, many authors from the French Enlightenment defended Descartes and the vortices, at a time when their scientific truthfulness was seriously questioned.

⁹These research areas motivated a growing interest in the structure of the Universe – a Universe that was gradually conceived as larger and more complex with the passing of time, and went from being based on vague suppositions to being confirmed by observations and measurements.

¹⁰For the quotes from this text I use an English translation done one century later. Since the English of the translation is as obscure as the original Latin, sometimes I add an explanation within the quote itself in order to make it easier to understand. The original edition was the first volume of *Opera philosophica et mineralia* (Swedenborg 1743).

Hence may arise new heavens one after the other; in these heavens, new vortices and mundane [i.e. planetary] systems; in these vortices and systems, new planets; around the planets, new satellites (Vol. 2 Swedenborg 1846, p. 240).

Swedenborg identified two notions from which to analyze the cosmos: its “figure and motion or, geometry and mechanism” (Vol. 2 Swedenborg 1846, p. 261) – what we would now call its ‘structure’ and ‘evolution.’ Following these parameters, he explained the process of the formation of the Solar System, which took place within the solar vortex. As stated by the vortex hypothesis, the particles are always in motion. According to that, Swedenborg defined the Universe as an “active space” many times.

In the beginning, all matter in the Solar System was condensed around the Sun, like a crust. By the action of its intrinsic motion, this matter separated from the center (i.e. the proto-Sun) and expanded itself until it reached the borders of the solar vortex:

[This crust of matter], being endowed with a continual gyratory motion round the sun, in the course of time removes itself farther and farther from the active space [i.e. the Sun at the center]; and, in so removing itself, occupies a larger circle of space (Vol. 2 Swedenborg 1846, p. 261).

When this matter reaches the border of the vortex, it collapses and forms a kind of belt that is still rotating round the Sun. Since the motion does not cease, the belt or ring naturally continues evolving: it condensates and forms planets and satellites. After the system has been formed, Swedenborg considered different possibilities for its later evolution: it could subside inwardly or outwardly toward another system but, in general, the proto-solar system should reach equilibrium with the volume of the vortex.¹¹ For the Swedish scientist this process of consecutive transformations (first, expansion in all directions; second, formation into a ring; third, transformation into “larger and smaller globes”, that is, the heavenly bodies) was a scientific fact:

That the expanse becomes attenuated in consequence of forming a larger circle, is a purely geometrical fact (Vol. 2 Swedenborg 1846, p. 262).

The expression “active space” is continually used to refer to the Universe or parts of it. As well, the noun “expanse” was also used frequently to describe the process taking place in the formation of the Solar System, such as in this case:

That this belt, which is formed by the collapse of the crustaceous expanse [i.e. the expansion of the crust], gyrates in a similar manner; removes itself to a farther distance; and by its removal becomes attenuated till it bursts, and forms into larger and smaller globes; that is to say, forms planets and satellites of various dimensions (Vol. 2 Swedenborg 1846, p. 262).

¹¹Let us note that for Swedenborg, the “vortices” are like a container where the “systems” are formed. The explanation of Swedenborg was echoed (via Kant) by Pierre-Simon Laplace (1749–1827) in the famous Kant-Laplace nebular hypothesis for planetary system formation; see Laplace (1796). Nevertheless, Laplace did not mention Swedenborg as a source, and exclusively mentioned Georges Louis Leclerc, Comte of Buffon (1707–1788), as the only person who had seriously dealt with cosmology so far. Contrary to Swedenborg, Laplace put more emphasis on the role of gravity in the formation process.

Swedenborg did not conceive of the expansion of the Universe in the same terms as we understand it today. Nevertheless, he put emphasis on a key consequence of the physical model based on vortices that was not expressed so clearly before: the expansion of the systems as a natural process of their evolution. From a dense, small area, by their intrinsic spinning motion, the systems progressively become larger:

The tendency of the crust is to fly off [the center] to a greater distance (Vol. 2 Swedenborg 1846, p. 262).

Like other authors under the influence of the plurality of worlds, Swedenborg understood that the Solar System was the essential piece in the construction of the Universe. For him, describing the process of the formation of the Solar System implied giving an explanation of the formation of planetary systems in general, which concerned the cosmic structure as a whole. Therefore, the implications of his description of the formation of the Solar System went beyond the system itself, which was assumed as a model to be applied to the general structure. Insofar the authors of this period used to operate by analogy (explaining the observed phenomena of the Solar System in terms of generalizable phenomena), the cosmogony of many authors, like Swedenborg, can be understood as general cosmology – at least, it was so for them.

5. The Milky Way and the nebulae come into play

When in 1750 Thomas Wright of Durham (1711–1786) published *An Original Theory or New Hypothesis of the Universe*,¹² the idea of the plurality of worlds had already been established and validated by a century of intense discussions, a number of publications and diverse reactions.

Wright's principal goal was to integrate the new structure of the Universe into a religious worldview. The English astronomer applied to the usual picture of the cosmos in the 17th and 18th centuries a personal (thus the “original” included in the title of the book), ambitious and obscure religious order in which God and moral values acquired the same status in the physical world as the stars and the planets. According to him, the Universe is composed of an infinite number of autonomous entities similar to our System, which, following the common notions from the plurality of worlds, can be planetary or star systems that can contain (inhabited) planets or only stars:

[...] the visible Creation is supposed to be full of siderial [sic] Systems and planetary Worlds, so on, in like similar Manner, the endless Immensity is an unlimited Plenum of Creations not unlike the known Universe (Wright 1750, p. 83).

Despite the fact that the religious aspect was fundamental to his thoughts and encompassed his main concerns, it is important to mention him in this context for one reason: the role he conferred to the Milky Way and the nebulae as starting points for shaping a hypothesis about the structure of the Universe.

¹²For a comprehensive analysis of Wright's hypothesis see the reprint and introduction by Michael A. Hoskin (Wright 1971).

He asserted that “there are other luminous Spaces in the starry Regions, not unlike the Milky Way” (Wright 1750, p. 42). After explaining his bizarre ideas of spheres within spheres that have God as the common center of the heavenly bodies in each system (or “Creation”), he argued that the nebulae observed in the sky prove his ideas, since they are actually the distant systems he describes:

That this [the Universe structure he proposed] in all Probability may be the real Case, is in some Degree made evident by the many cloudy Spots, just perceivable by us, as far without our starry Regions, in which tho’ visibly luminous Spaces, no one Star or particular constituent Body can possibly be distinguished; those in all likelihood [sic] may be external Creation, bordering upon the known one, too remote for even our Telescopes to reach (Wright 1750, pp. 83-4).

Regarding the Milky Way, Wright stated:

[H]ow far I have succeeded in my designed Solution of the *Via Lactea*, upon which the Theory of the Whole is formed, is a Thing will hardly be known in the present Century, as in all Probability it may require some Ages of Observation to discover the Truth of it (Wright 1750, p. 66).

According to him, the “Milky Way” we see crossing the sky is the product of a visual effect. For him it has in fact a spherical shape, and is like a shell. The Solar System is embedded in it; thus, we observe the shell of the Milky Way through a tangent view from within. Although this reasoning does not really work, he saw in it a proof for the impression that the system is the shape of a plane. Hence, his famous description of the Milky Way was presented as a supposition, since for him the plane is a visual effect and not its actual shape:

Let us imagine a vast infinite Gulph, or Medium, every Way extended like a Plane, and inclosed between two Surfaces, nearly even on both Sides (Wright 1750, p. 62).

In other words, within his system our Galaxy was a sphere, but we perceive it as a plane because we are immersed in the middle of its shell. Consequently, “to an Eye situated near the Center Point,” the Galaxy appears to be a “Zone of Light.”

He insisted on the fact that this explanation concerns only the visible aspect of the Universe that is accessible to our senses (i.e. as an optical effect), but is not its real structure. He presented this hypothesis as a possible explanation of what we see in the sky but, as he asserted, “I don’t mean to affirm that it really is so in Fact” (Wright 1750, p. 62). For him, what was really important was to reconcile the real structure of the cosmos with “the visible Order of its Parts,” in this case, the observed Milky Way. This task was obviously hard to fulfill, since his cosmic model was founded on false grounds and was extremely complex due to mixing physical phenomena with religious elements.

Wright failed to outline a correct (and even reasonable) structure of the Universe, but he did foresee that the Solar System, as traditionally argued in the plurality of worlds by then, was not the proper unit to consider regarding the general scale; instead, it was an element of a larger structure composed of systems with a much bigger size. These

aspects of his hypothesis (or ‘theory’ according to his own terminology), although being secondary elements within his worldview, acquire relevance in view of the future development of astronomy.

Only five years after the publication of *An Original Theory* by Wright, and at the age of 31, Immanuel Kant (1724–1804) brought out the *Allgemeine Naturgeschichte und Theorie des Himmels* [Universal Natural History and Theory of Heaven] (Kant 1755).

Contrary to popular opinion, the term ‘island universes’ never appears as such in the *Theorie des Himmels*, although the idea behind it has a notable presence. Kant did discuss other systems that are similar to the Milky Way, and he referred to them using expressions like “similar systems” (ähnliche Systeme), “Systemata”, “world systems” (Weltgebäuden, Weltsystemen), “world orders” (Weltordnungen), “heavenly hosts” (Himmelsheere), or “solar systems” (Sternensysteme). The word ‘island’ (Insel in German) appears a couple of times in this book, but to refer to a real island (Jamaica), or as a metaphor applied to planets without inhabitants.¹³

By the middle of the 18th century, when Kant published this book, the concept of the plurality of worlds was already well-established and was a common topic of discussion in both specialized and popular literature. In fact, he used the same expressions (see the terms listed above) that were usual in this field to designate the structural components of the Universe. But Kant went further and gave the best description (in a contemporary sense) of the cosmic structure so far.¹⁴

Instead of talking about the concept of island universes, Kant defined what he called a “systemic constitution of the Universe.”¹⁵ In essence, it involved the definition of the components of the Universe’s structure as ‘systems’: the Solar System was the basic element; it belonged to the category of planetary systems, which were associated with the stars seen in the sky (each star was considered to be a sun, in the sense of forming a planetary system); a group of many planetary systems, including ours, forms the Milky Way, which was also defined as a system (and described as a plane that constitutes an area of relationships – or “relational area” – caused by its gravitational forces, in which all elements are rotating round its center and whose general shape is elliptic); finally, the nebulae are also systems with similar characteristics to the Milky Way and which are so far away from us that their constitutive heavenly bodies blur themselves in a misty appearance. Therefore, Kant’s worldview was an intermediary step between the plurality of worlds and more modern day conceptions.

He defined our Galaxy as follows:

The shape of the heavens of the fixed stars has no other principle than the same system constitution in large that the planetary world-edifice [i.e. the Solar System] has in small, inasmuch as all suns form a system whose general relational plane is the Milky Way (Kant 1755, p. 8).¹⁶

¹³He mentioned that the regions of the sky without any inhabited planet are like a “desert or island” (“eine Wüste, oder Insel”) in the ocean of the Universe (Kant 1755, p. 175).

¹⁴Contrary to Wright, Kant expressed his ideas very clearly without metaphors or obscure analogies, and exclusively pursued scientific goals.

¹⁵Literally: “systemische Verfassung des Weltbaues.”

¹⁶“Die Gestalt des Himmels der Fixsterne hat also keine andere Ursache, als eben eine dergleichen systematische Verfassung im Grossen, als der planetische Weltbau im Kleinen hat, indem alle Sonnen ein

This quote summarizes the detailed description of the structural components of the Universe expounded in the first part of his book. He built his hypothesis on several steps woven according to increasing scales.

First, he considered that the structure of the Solar System has a similarity with the structure of other neighboring systems:

[...] the fixed stars, just like many suns, are the center of similar systems, all of which may be arranged just as big and as ordered as in our system (Kant 1755, p. 2).¹⁷

Second, he stated that all together, they belong to the same entity, namely the Milky Way. For Kant the Milky Way is a big system composed of many star or planetary systems, all with a similar basic structure and characteristics but of a different size and with different elements. He recognized that our Galaxy generates an “area of relationships” which, by virtue of gravitational forces, bunch all the galactic celestial bodies and systems together. He explained how the gravity generated by the Galaxy acts upon the systems belonging to it in a similar way such that the gravity produced by the Sun acts upon the celestial bodies of the Solar System, and likewise the gravity of the other stars has an effect on the respective planetary systems that they form.

In a third step, he followed Wright’s hypothesis that nebulae are systems that are similar to the Milky Way. After explaining some of the characteristics of nebulae, he convincingly asserted that:

All this agrees so completely that we should consider these elliptic figures [i.e. the nebulae] as similar world orders, so to speak, Milky Ways (Kant 1755, pp. 14-5).¹⁸

The German philosopher took a step further than Wright and asserted that the plane ascribed to the Milky Way was not a mere optical effect far from reality, but a hint of its actual shape. According to that, its appearance in the sky is in fact due to its actual shape as a disk, and because the Solar System, from which we observe, is embedded in its plane. To him, this is an “undoubted phenomenon” (Kant 1755, p. 4).

Furthermore, Kant linked (again by analogy) the rotating motion of the Solar System to the entire Galaxy. He even brought the appearance of new stars into question, asking himself if it might be the case that the rotation of the Galaxy causes certain heavenly bodies to become visible or invisible to us depending on their position at each moment.

System ausmachen, dessen allgemeine Beziehungsfläche die Milchstrasse ist.”

Note: I prefer to give my own translation of Kant’s quotes, since some important concepts are missed or not satisfactorily interpreted in the official translations I have consulted.

¹⁷“[...] die Fixsterne als eben so viel Sonnen, Mittelpunkte von ähnlichen Systemen seyn, in welchen alles eben so groß und eben so ordentlich als in den unsrigen eingerichtet seyn mag.”

¹⁸“Alles stimmt vollkommen überein, diese elliptische Figuren vor eben dergleichen Weltordnungen, und so zu reden, Milchstrassen zu halten.”

Kant followed the French astronomer Pierre-Louis Moreau de Maupertuis (1698–1759), who observed that many nebulae are not a perfect circle or sphere, but that they indeed have an elliptic shape (Maupertuis 1732). Kant was absolutely convinced of this and, as he usually operated by analogy, concluded that the Milky Way must also be an elliptic disc.

To Kant, this description of the Universe's structure is nothing but obvious. For instance, he was astonished by the fact that earlier astronomers did not realize the shape of the Milky Way from its appearance in the sky, which is so clearly distinguishable:

It is surprising that the observers of the sky had not long ago been moved by the nature of this zone clearly distinguishable in the sky, to determine from it the peculiar position of the stars [that are part of it] (Kant 1755, p. 3).¹⁹

6. Conclusion

The structure, formation and evolution of the Universe were intensively discussed during the early modern period in Europe, becoming one of the most fascinating topics to affect the status of astronomy – a field in radical transformation at that time. On the one hand, the hypotheses presented above run parallel to the development of other aspects from the history of astronomy, mainly represented by Newton's ideas and his followers. On the other hand, they were the basis for future investigations, such as William Herschel's interest in nebulae.²⁰ These hypotheses, assumptions, and conjectures make possible a general awareness of the existence of many systems outside the observable and near cosmos. The curiosity, questioning, and revolutionary approaches that arose after them are an essential part of the evolution of astronomy in the context of the structure of the Universe, but also of the evolution of mentalities and philosophical paradigms that led to the modern worldview.

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¹⁹“Es ist zu bewundern, daß die Beobachter des Himmels durch die Beschaffenheit dieser am Himmel kenntlich unterschiedenen Zone nicht längst bewogen worden, sonderbare Bestimmungen in der Lage der Fixsterne daraus abzunehmen.”

²⁰For more information on the later evolution of the investigations of nebulae see Hoskin (2012); Jones (1969); Steinicke (2010).

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